Single Cycle Instrument Placement

This project is building and integrating the diverse capabilities for an exploration rover to rapidly and reliably do close up inspections and *in situ* measurements of objects in an unstructured and unpredictable environment or worksite, *with out* continuous operator supervision. This efficient goal level commanding capability represents an order of magnitude improvement in MER inspection capabilities whilst requiring less operator support.

Background

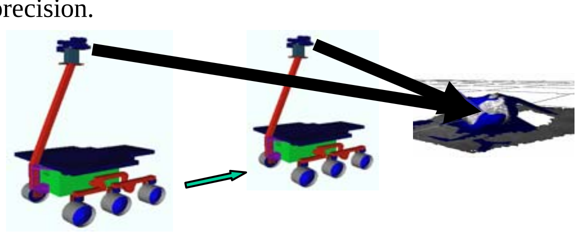
This research was motivated by the need of the planetary science community to acquire close up and contact measurements from a variety of targets on the surface of a planetary body. State-of-the-art planetary rovers, such as the MER rovers (Spirit and Opportunity) currently on Mars require 3 days and a standing army of operators on Earth to accomplish the task of driving up to a target and safely placing an instrument against it. With limited mission lifetimes and operations costs exceeding $1 million per day, decreasing this time and the number of operators has a significant scientific and cost-reduction pay-offs.

This project is building the capability for a rover to visit and examine multiple targets, scientific or otherwise, over 10's of meters in an un-prepared environment in one command cycle and without supervision from mission control. Using K9, a six wheeled planetary rover prototype, we have successfully demonstrated this in field locations, with operators at Ames communicating to it via satellite.

Research Overview

Achieving this has required us to make advances across a broad technological front:

• *Target tracking and instrument placement* technologies to enable a rover to autonomously visit and examine many samples distributed over a 10m radius area with centimeter precision.



Because of wheel slippage and cumulative inertial guidance position errors, a rover cannot keep accurate track of goal locations around it using deduced reckoning alone as it moves towards them. Our solution has been the development of stereo-vision techniques using keypoints

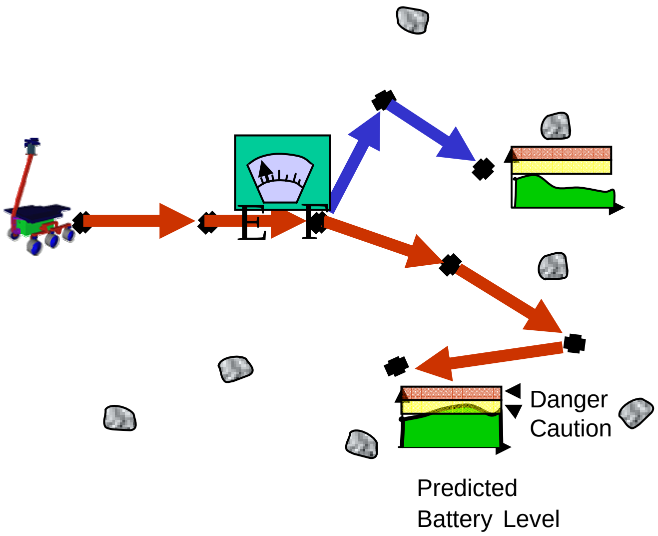
Once at the goal location, our auto-place algorithm permits the rover to distinguish rocks and other potential targets from the ground (regardless of slope or surface texture) and find instrument placements consistent with any limitations imposed by the tool and the target geometry.

• *Robust and flexible planning and execution* for the rover to accommodate the great uncertainty associated with navigating to and deploying instruments on multiple samples, whilst adhering to power and resource constraints characteristic of a planetary rover.

Standard mission practice is to generate daily activity plans offboard, permitting operators to modify and verify them prior to uplink. Whilst suitable for predictable systems, such as satellites in orbit, this approach

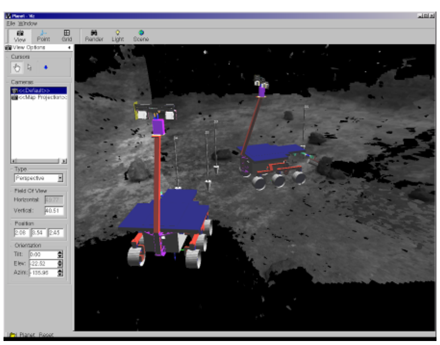
Single Cycle Instrument Placement

We have developed a ground based *contingency planner* that generates a main line rover activity sequence with flexible time constraints and contingent activity sequences to accommodate off-nominal behavior. These include diverting to closer targets if resource use is excessive and recovering from target tracking failures:



The rover *CRL Executive* executes these plans whilst monitoring resources and faults, and doing minor plan re-evaluations as required.
This approach combines the benefits of the traditional approach with some of the flexibility but not the risk of an onboard planner.

•Ground systems for users to rapidly identify, prioritize and specify many potential targets, evaluate the plan of action, and understand the data returned from the multiple samples the rover actually visited (which may differ from the highest priority set requested).
Our operator interface uses the Viz software to immerse users in a photorealistic VR, 3D display of the environment around the rover. Within this, the users rapidly specify daily mission goals and evaluate returned data.



Another tool, Merboard, facilitates collaboration amongst users and graphically displays forecast activities for and actual results from the rover.

Relevance to Exploration Systems

This project addresses H&RT needs for high level robotic goal commanding of exploration activities. Through this, communication requirements, number of operators, and astronaut EVA on lunar and planetary surfaces can be reduced. This directly reduces risk and cost.

H&RT Program Elements:

This research capability supports the following H&RT program /elements:

ASTP/Software, Intelligent Systems & Modeling

TMP/Lunar, Planetary and Surface Operations

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